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Control of FIELD BINDWEED by Cultural and Chemical Methods

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Contents

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Control of FIELD BINDWEED *by* *Cultural and Chemical Methods*[1]

By William M. Phillips, Research Agronomist,
Crops Research Division,
Agricultural Research Service[2]

Field bindweed (*Convolvulus arvensis* L.) is an aggressive deep-rooted perennial plant that has long been recognized as the most serious weed pest in many areas in the central and far western United States. It also ranks high among weed problems in the Corn Belt, in some Northeastern States, and in many parts of the South and Southwest.

Bindweed, a native of Europe and western Asia, according to Kiesselbach and coworkers (*9*),[3] first appeared in this country along the eastern seaboard. It was reported in Virginia in 1739, and was first reported in Kansas at Topeka in 1877. Frazier (*4*) thought it was probably brought to Kansas in seed wheat from the Ukrainian region of Russia between 1870 and 1875.

The first experiments on the control of bindweed in Kansas were conducted in 1907 and 1908 on a farm near Victoria, Ellis County, under the direction of A. M. Ten Eyck of the Kansas Agricultural Experiment Station. Experiments involving the use of salt, cultivation, and smother crops were begun at the Fort Hays Branch Station in 1915 by R. E. Getty of the U.S. Department of Agriculture. The results of these experiments conducted over a period of years were reported by Call and Getty (*3*) in 1923.

Early reports from other States on bindweed control include those of Bioletti (*2*) and Gray (*5*) of California in 1911 and 1917, and Stewart and Pittman (*24*) of Utah in 1924. Latshaw and Zahnley (*10*, *11*) reported in 1927 and 1928 the results of experiments with sodium chlorate on bindweed control in Kansas. From 1929 to 1934 many investigators, including Schafer and coworkers (*21*), Kennedy

[1] Cooperative investigations of the Agricultural Research Service, U.S. Department of Agriculture, and the Kansas Agricultural Experiment Station. These investigations were conducted at the Fort Hays Branch Station, Hays, Kans., during the period 1935–58.

[2] Acknowledgment is due F. L. Timmons, research agronomist, Agricultural Research Service, who was in charge of the work from 1935 to 1948.

[3] Italic numbers in parentheses refer to "Literature Cited" p. 26.

and Crafts (*8*), Willard (*30*), Hulbert and others (*7*), Tingey (*29*), and Kiesselbach and others (*9*), reported results with cultivation, chlorates, and other methods of controlling field bindweed. In recent years many investigators have published results on the control of bindweed with selective and soil-sterilizing chemicals. Most of these data have been published in abstract form in reports from the several regional weed control conferences in United States and Canada.

The investigations reported in this bulletin were begun July 1, 1935. The experimental plots were located on a 130-acre tract of bindweed-infested land adjacent to the Fort Hays Branch Experiment Station. They were part of a coordinated Federal-State regional research program in which projects were also established in 1935 and 1936 at Geneseo, Idaho, York, Nebr., Lamberton, Minn., and Hawarden, Iowa. Preliminary reports of the investigations at Hays, Kans., were published in 1939 [4] and 1941 (*25*), and certain completed phases were published in 1950 (*27*), 1951 (*28*), and 1954 (*20*). Brief reports of results with several soil-sterilizing chemicals (*12*, *13*, *14*, *15*, *16*) and more detailed reports on the use of certain chlorinated benzoic acids (*17*, *18*, *19*) were published by Phillips.

Published reports on the coordinated program in other States have been made by Seely (*22*) and coworkers (*23*), Bakke and others (*1*), Hanson and coworkers (*6*), and Wilson and coworkers (*31*). No attempt has been made to review all the literature, but the references listed on pages 28 to 30 relate directly to field bindweed control.

This bulletin summarizes the more important results of 24 years of bindweed control investigations at the Fort Hays Branch Experiment Station. The conditions under which the experiments were conducted are described, so readers may judge the application of the results to their localities and situations.

EXPERIMENTAL CONDITIONS

Climatic Conditions

Precipitation probably is the most important of the several climatic factors that may influence results of bindweed control experiments. Table 1 summarizes the precipitation received at Hays, Kans., for 24 years. The yearly precipitation as well as the amount of rainfall received during the growing season varied considerably. The yearly range was from 9.21 inches in 1956 to 43.34 inches in 1951. The years of 1936, 1937, 1939, 1943, 1952, and 1956 were extremely dry. Rainfall distribution in 1953, 1954, and 1955 was such that drought conditions prevailed during much of the growing season. Lack of moisture reduced yields of most crops in the year of low rainfall and also the following year, owing to lack of subsurface moisture. Moisture, in general, was favorable in the years 1940 through 1951 and in 1957 and 1958. Considerably more than average rainfall was received during several of those years. However, the annual and seasonal aver-

[4] TIMMONS, F. L., EVANS, L. S., STAHLER, L. M., and SEELY, C. I. PROGRESS REPORT OF COOPERATIVE WEED INVESTIGATIONS. U.S. Dept. Agr. Bur. Plant Indus. Mimeo. Rpt. 1939. [Processed.]

ages for 1935 to 1958 were comparatively little different from the 91-year average, 1868–1958.

In general, the years of low rainfall had relatively high temperatures. The combined effect of deficient moisture and unusually high temperatures resulted in conditions extremely unfavorable for crops and for weed control experiments.

TABLE 1.—*Precipitation recorded at Hays, Kans., 1935–58* [1]

Year	Seasonal Apr. 1–Sept. 30	Total	Year	Seasonal Apr. 1–Sept. 30	Total
	Inches	*Inches*		*Inches*	*Inches*
1935	18.09	21.87	1947	17.52	22.65
1936	12.30	15.90	1948	19.53	26.19
1937	13.93	17.86	1949	17.13	23.62
1938	19.20	22.11	1950	21.57	25.59
1939	12.35	15.85	1951	37.45	43.34
1940	16.99	22.91	1952	9.06	13.39
1941	21.66	28.13	1953	14.11	21.07
1942	23.42	29.61	1954	15.65	18.56
1943	12.82	16.19	1955	19.42	21.16
1944	21.21	29.70	1956	7.00	9.21
1945	17.46	20.34	1957	23.48	28.33
1946	17.38	26.48	1958	24.82	31.21

[1] Average seasonal, 1935–58, 18.06 inches; 1868–1958, 17.64 inches. Average total, 1935–58, 22.97 inches; 1868–1958, 22.90 inches.

Soil Type

The experimental area at Hays consists mostly of level to slightly rolling upland. The soil, a Crete silty clay loam, has somewhat finer texture than many of the upland soils in west-central Kansas. The surface 12 inches is a medium heavy, dark silty clay loam. The subsoil is heavier, more compact, and lighter colored. The soil has a high moisture-holding capacity and is capable of producing high yields of crops under favorable moisture and other climatic conditions. Its heavy character makes some farming operations rather difficult unless moisture conditions are ideal.

Bindweed Growth

When the experimental work on bindweed at Hays was undertaken in 1935, the infestation was complete and remarkably uniform on about two-thirds of the area. The remaining one-third contained numerous bindweed spots.

Bindweed growing on the experimental area was, in general, relatively shallow rooted (fig. 1). More than 70 percent of the total weight of roots in the top 6 feet of soil was in the surface 2 feet.

The growing season for bindweed at Hays averages about 7 months.

FIGURE 1.—Field bindweed growth typical of the experimental area.

Spring emergence usually begins early in April and growth continues until November or until minimum temperatures of 20° F., or lower, occur. Temperatures from 20° to 30° retard bindweed growth but do not kill the vines.

Normally, heaviest bindweed bloom in the Hays vicinity is from May 15 to June 15, and seed maturity begins from June 15 to July 15. Bindweed seed usually matures before grain harvest in infested fields. When sufficient moisture is available, the bindweed continues to bloom and produce seed during August and September. In seasons of low summer rainfall, the bindweed often becomes dormant in July and then starts new growth in late August or early September (fig. 2). If dry conditions continue through the fall, little regrowth is made in the latter part of the growing season.

EXPERIMENTAL PLAN

The experiments undertaken at the beginning of the project were to give information on many phases of bindweed control. They covered root-reserve studies; frequency, time of beginning, and depth-of-cultivation studies; use of competitive crops; and comparisons of different dates, rates, and methods of applying sodium chlorate and other chemical treatments. In 1946 and later, the program included investigations with chemical control by 2,4-D and combinations of

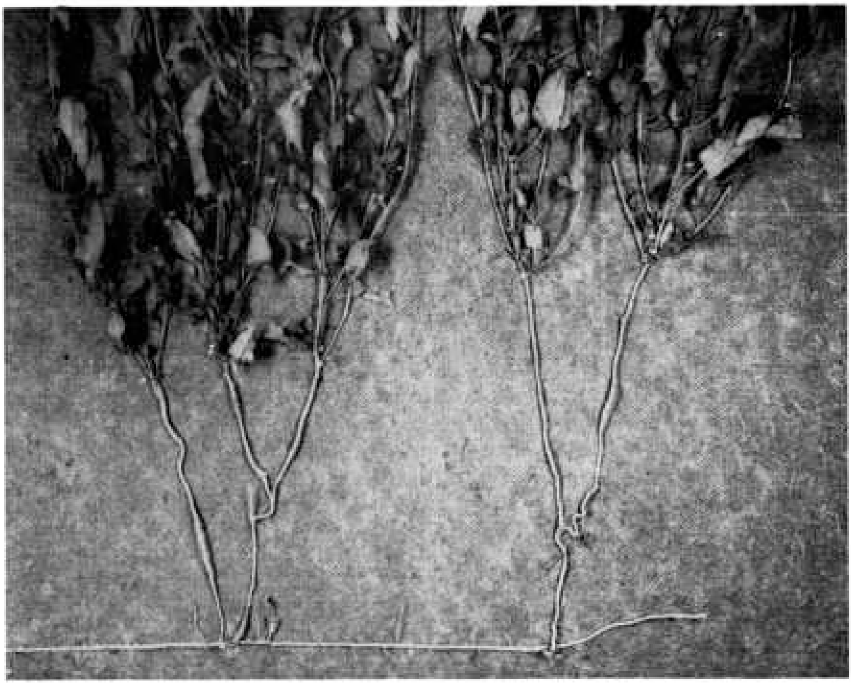

FIGURE 2.—Field bindweed shoots from a short section of a lateral root.

2,4-D with competitive crops and with intensive cultivation. Since 1950, many soil sterilizing-type chemicals have been tested.

Effectiveness of the various treatments was determined by making numerous counts of surviving plants throughout the course of the experiments. When the stand of bindweed was so dense as to prohibit counting all plants on a given plot, a meter-square quadrat was used. The number of samples per plot varied with the plot size, but at least four 1-meter-square quadrats were used on all plots. The resulting counts were converted to a plants-per-square-rod basis. After a treatment had caused some stand reduction, the entire plot served as the sample. Again these counts were converted to a square-rod basis.

Most data herein are reported as number of surviving plants. Bindweed growth varies considerably throughout the growing season; thus, plant counts made on a given area at different times may vary greatly. Since experiments were started at various times during the year, plant counts made at the beginning of the experiment would not necessarily reflect the true level of infestation.

Many factors affect the number of plants that may be growing at a given time. For example, cultivation at 5- to 6-week intervals may more than double the number of emerged plants, as compared to undisturbed areas.

Because of these variables, all experiments were started on land heavily infested with bindweed, and then the effectiveness of the various treatments was compared by checking the number of surviving weed plants. In order to make the data from a given type of experiment as comparable as possible, plant counts made in the same season of the year were used in preparing the tables.

It should also be pointed out that surviving plants do not necessarily reflect the true degree of bindweed control. For example, two chemical treatments might allow the survival of 50 plants per square rod. In one case all plants might be normal and vigorous; in the other treatment they might be small and weak and exhibit abnormal growth habits.

Crop yields were recorded in experiments that involved crop competition. All treatments were replicated two or more times in each experiment. Most types of experiments were repeated on new plots every year over periods of 3 to 10 years. In many experiments treatments were continued until the bindweed was completely eradicated by the most effective methods. This was done to determine, as well as possible, the effect of seasonal variation upon results. The experimental plots ranged from one-half square rod for some of the screening tests of new chemicals to one-twentieth acre or more for cultivation and competitive cropping experiments.

EXPERIMENTAL RESULTS

Effect of Bindweed on Crop Yield

A series of experiments were started in 1936 and continued each year through 1947, testing the effect of bindweed on the yield of eight different crops (*20*). This period covered a wide range of growing conditions. In some years yields were extremely low for nearly all crops. In other years the yields were quite high, and the 12-year average indicates that over the period nearly average yields were obtained on land not infested with bindweed.

The methods of planting and cultural practices followed were comparable to average farm practices. Only about half of the area used for these experiments was infested with bindweed. Yields were determined separately on infested and noninfested areas for each crop.

Grain yields of six different crops were reduced by bindweed infestations from a minimum of 20 percent for rye to a maximum of 78 percent for milo (*20*). Forage yields were reduced from 37 percent in drilled sorgo to 51 percent in milo (*20*). The small-grain crops, competing with bindweed, produced relatively greater average yields than did kafir or milo. The apparent reason for this difference seemed to be that wheat and other grain crops actively competed with the bindweed only from about May 1 to harvest, about July 1. Whereas the sorghum crops, normally planted about June 1, competed with bindweed throughout their growing season, until October 1 or later. The bindweed usually reduced yields of crops considerably in both wet and dry years, but the percentage reduction was greater in dry years.

Through the 12 years wheat averaged 5.2 bushels, barley 10.7 bushels, and oats 13.5 bushels more on noninfested land than on land infested with bindweed. Close-drilled sorgo and sudangrass competed more effectively with bindweed than did row-planted kafir and milo, so that the forage yields were not reduced so much as were yields of row-planted crops. Results of these experiments indicated that it is impractical to raise milo or kafir on land heavily infested with bindweed.

Controlling Bindweed by Cultivation[5]

Numerous experiments were conducted on time of the year to begin cultivation, frequency of cultivation, depth of cultivation, time to stop cultivation, and best type of implement to use to control bindweed for the 1936–47 period (*20*).

Results of the study showed cultivation operations must be performed with an implement that will cut completely all bindweed shoots and, thus, prevent additional food storage in the root system. Cultivation operations performed 12 days after each bindweed emergence resulted in bindweed eradication with an average of 16.2 cultivations. This compared with an average of more than 32 cultivations when the operation was performed each time the bindweed emerged. No advantage was found for cultivating bindweed deeper than necessary to cut off all plants well below the surface (fig. 3). The optimum depth in the medium heavy soil at Hays was 4 inches.

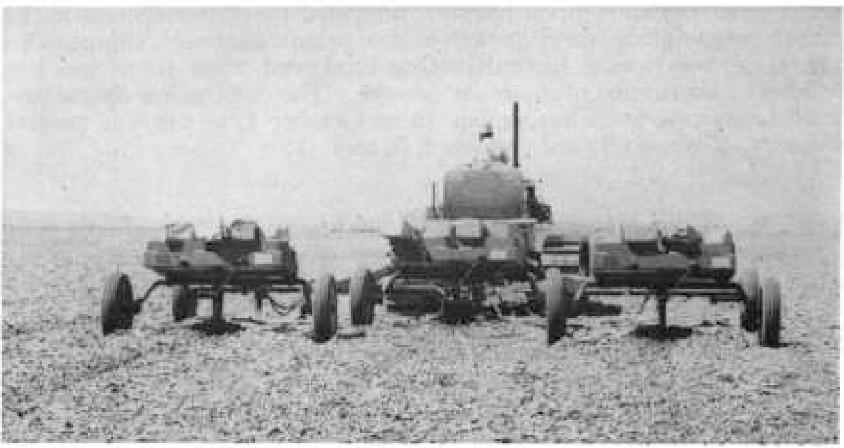

FIGURE 3.—A large sweep-type implement well suited for cultivation of extensive infestations of field bindweed.

For practical use, it appears that cultivation operations could be every 2 weeks during the first 2 or 3 months of the treatment or until the bindweed has been weakened and emerges more slowly (fig. 4).

[5] The term "cultivation" as applied to bindweed throughout this publication refers to a tillage operation in which all the soil surface was undercut and all plant growth, including bindweed, was cut off. This is quite different from the meaning of cultivation as applied to corn, sorghum, and other row crops.

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FIGURE 4.—Field bindweed plants 16 days after emergence in one of the interval-of-cultivation experiments.

The interval then may be safely lengthened to 3 weeks. The cultivation may be started either in the spring soon after bindweed growth starts or after small-grain harvest, provided there is sufficient moisture to promote bindweed growth and to permit thorough tillage. No advantage was found for cultivating bindweed when there was not sufficient moisture to promote its growth. The cultivation operations should continue until September 15 or October 1, to prevent partial recovery of the bindweed (tables 2, 3, and 4).

TABLE 2.—*Average number of cultivations necessary to eradicate field bindweed as affected by the frequency of cultivations, 1936–43* [1]

Cultivation after emergence (days)	Interval between cultivations first year	Cultivations necessary for eradication	Crop seasons required for eradication
	Days	*Number*	*Number*
0	8.3	32.3	1.8
4	12.3	23.2	1.7
8	16.7	19.2	1.8
12	20.8	16.2	1.9
16	25.2	16.1	2.2
20	28.2	21.9	3.4
28	37.0	[2] 23.4	[2] 3.7

[1] Adapted from Phillips and Timmons (*20*).
[2] Eradication was never completed on both replicates during the course of the experiments.

TABLE 3.—*Summary of results from date of beginning cultivation experiments, 1936–39* [1]

Approximate date cultivation was begun the first year of experiment	Average total cultivations required for eradication in 4 experiments started 1936–39
	Number
First emergence in spring	18. 1
May 1	17. 4
June 1	15. 9
July 1 (after small-grain harvest)	17. 6
Aug. 1	16. 3
Sept. 1	16. 1

[1] Adapted from Phillips and Timmons (*20*).

TABLE 4.—*Summary of results from experiments on average time of stopping cultivation of bindweed in the fall, 1943–50* [1]

Time of last cultivation in the fall [2]	Cultivations required to eradicate bindweed	Years of cultivation treatment required to eradicate bindweed [3]
	Number	*Number*
Spring series—cultivation began in spring:		
Sept. 1	23. 1	3. 1
Sept. 15	21. 4	2. 6
Oct. 1	20. 1	2. 2
Oct. 15	20. 2	2. 1
Summer series—cultivation began after small-grain harvest of first year:		
Sept. 1	20. 3	2. 4
Sept. 15	21. 3	2. 1
Oct. 1	22. 5	2. 0
Oct. 15	23. 3	2. 0

[1] Adapted from Phillips and Timmons (*20*).
[2] All plots were seeded to winter wheat immediately after the last cultivation each fall. The crop was destroyed and cultivation resumed the following spring as soon as bindweed began growth.
[3] Expressed as the number of years in which a grain crop could not have been grown due to the cultivation treatment.

Controlling Bindweed With Competitive Crops and Intensive Cultivation

Results from experiments for 1935 to 1952 showed that good crops can be grown on bindweed-infested land and the bindweed controlled at the same time (*20*). One year of intensive fallow and three crops of wheat seeded early in October after intensive cultivation between harvest and seeding each year eradicated bindweed in 3 to 4 years and proved to be a practical plan for the Hays, Kans., region (fig. 5).

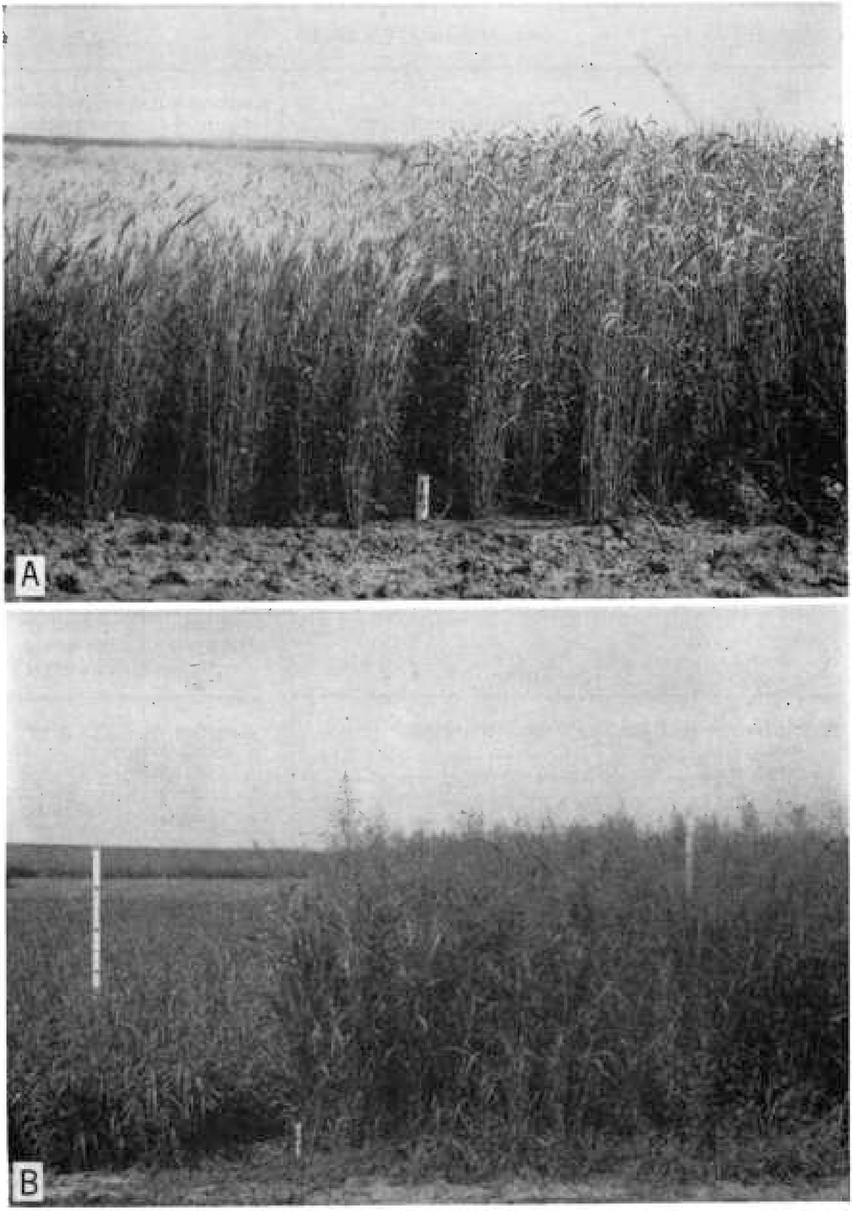

FIGURE 5.—Competitive crops for bindweed control: *A*, wheat (left), and rye (right); *B*, millet (left), and sudangrass (right).

Alternate fallow and wheat and a rotation of 1 year of fallow and 2 years of wheat also appeared to be good methods to use in areas where such a farming system is regarded as sound practice. These methods require no change in the practices already followed by progressive wheat farmers, other than timely and thorough cultivation at 2- to 3-week intervals when the land is not in crop.

Close-drilled sorgo or sudangrass seeded about July 1 after a period of intensive cultivation proved to be effective competitors with field bindweed. The success of all competitive crops depends upon intensive cultivation during the bindweed-growing season when the land is not in crop, and upon obtaining a good stand of the crop.

Controlling Bindweed With Soil-Sterilizing Chemicals[6]

The soil-sterilization experiments were conducted on square-rod plots, with each treatment duplicated or triplicated. In most instances, the experiments were started in a number of succeeding years in an effort to measure the effect of various climatic conditions on the results obtained.

Prior to 1950 sodium chlorate was subjected to many comprehensive experiments (*20*). Because of the thorough testing and its widespread use, sodium chlorate is used as a standard of comparison for the following soil-sterilizing chemicals that were evaluated in numerous experiments: Sodium chlorate, several borates, borate-sodium chlorate mixtures, monuron, fenuron, monuron-borate and monuron-borate-sodium chlorate mixtures, chlorinated benzoic acids, and high rates of 2,4-D, 2,4,5-T, and silvex. In addition, several other chemicals, including erbon, amitrole, and simazine, were used in a few experiments.

Sodium Chlorate

Experiments were conducted during 1936–45 to determine the most suitable time of the year to apply sodium chlorate, the most satisfactory method of applying, and the most effective rate of application (*20*).

Little difference was noted in results of spray or dry applications of sodium chlorate. Results with rate and date of application of sodium chlorate were somewhat variable from year to year, but it appeared that September and October were the most favorable months to apply this chemical. It is not generally practical to apply enough chlorate at one application to completely kill all bindweed. An original application of 3 to 4 pounds per square rod, followed by retreatments in subsequent years, generally has been the most economical method at Hays. Less chemical was needed for eradication when retreatments were delayed until October of the year following the initial application or until May or September of the second year than when retreatment was started early in the first year after the original application.

WARNING—When clothing, dry vegetation of any kind, unpainted boards, and similar flammable materials are wetted with sodium chlorate solution and allowed to

[6] The terms "sterilizing chemicals" and "sterilant" refer to chemicals that make the soil incapable of supporting plant growth. A list of the chemicals is on page 30.

dry, they may be ignited easily by friction, sparks, or the heat of the sun, and will burn violently with intense heat. Instances have been reported in which operators were severely or even dangerously burned in this way.

Dry applications are not entirely free of fire hazards, particularly when vegetation is wet with dew or rain. Care should be taken so there is no opportunity for the chemical to collect on vegetation or in clothing such as in trouser cuffs or pockets, nor to be spilled in or around buildings where there is flammable litter. Gloves should not be worn while handling chlorate. Sodium chlorate is poisonous to animals when consumed in considerable quantity; therefore, livestock should not be allowed to range over areas that have been treated recently.

Chloro-Substituted Benzoic Acids

Most experimental work from 1955 through 1958 was done with three chloro-substituted benzoic acids. The compound designated as 2,3,6-TBA consisted of approximately 60 percent 2,3,6-trichlorobenzoic acid and smaller percentages of various isomers. The polychlorobenzoic acid (PBA) consisted primarily of several isomers of dichloro- trichloro- and tetrachlorobenzoic acid. The third compound, designated as TBA, was made up of approximately 50 percent 2,3,5-trichlorobenzoic acid, 20 percent 2,3,6-trichlorobenzoic acid, and smaller percentages of other isomers. The TBA used was formulated as an emulsifiable oil. Several formulations of the other two compounds were tested.

Comparatively few applications were made in 1955 and 1956. Results obtained from these exploratory treatments served as a basis for the wider range of rates and formulations used in 1957 and 1958.

Table 5 compares 16 and 32 pounds per acre 2,3,6-TBA, and 16, 32, and 48 pounds per acre TBA and PBA with 960 pounds per acre sodium chlorate. According to data collected in the fall of the first year after treatment, 2,3,6-TBA at 16 and 32 pounds per acre was consistently more effective than sodium chlorate. The greater stand reductions were particularly evident in the experiments started in the dry years of 1955 and 1956. The action of sodium chlorate may be delayed during dry weather; therefore, the number of bindweed plants that remained 1 year after treatment with sodium chlorate in 1955 and 1956 may be abnormally high. Likewise, excessive precipitation may leach sodium chlorate rapidly, thus permitting bindweed regrowth. Variation in precipitation appeared to have less effect on the action of 2,3,6-TBA than on sodium chlorate.

When plant counts taken in the fall of the second year after treatment are considered, it is evident that the differences in control between sodium chlorate and 2,3,6-TBA were considerably reduced. In most cases comparatively small changes were recorded during the second year on plots treated with either 16 or 32 pounds per acre 2,3,6-TBA, but in all cases the effectiveness of sodium chlorate increased (fig. 6).

Table 5.—*Average number of bindweed plants per square rod in the first and second year after treatment with sodium chlorate, 2,3,6-TBA, TBA, and PBA at Hays, Kans., 1955–58. All plant counts were made in the fall*

Chemical	Rate	Time after treatment	Surviving plants after treatment in— May 1955	October 1955	July 1956	November 1956	May 1957	July 1957	October 1957	May 1958	July 1958	October 1958
	Lb. per acre		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Sodium chlorate	960	1st year	98	135	16	156	26	4	22	16	24	74
		2d year	46	32	4	24	14	1	6	------	------	------
2,3,6-TBA	16	1st year	14	24	------	90	------	16	2	15	4	8
		2d year	30	6	------	36	------	24	3	------	------	------
	[1] 32	1st year	10	2	------	6	------	1	20	4	------	------
		2d year	11	8	------	4	------	1	35	------	------	------
TBA	16	1st year	------	------	12	174	115	22	10	------	------	------
		2d year	------	------	20	225	171	30	4	------	------	------
	[1] 32	1st year	------	------	16	15	78	3	24	------	------	------
		2d year	------	------	10	132	194	8	23	------	------	------
	48	1st year	------	------	------	------	46	1	10	------	------	------
		2d year	------	------	------	------	26	0	12	------	------	------
PBA	16	1st year	------	------	36	266	250	18	44	42	------	------
		2d year	------	------	100	131	200	11	90	------	------	------
	[1] 32	1st year	------	------	56	68	242	27	14	7	2	14
		2d year	------	------	79	22	250	36	11	------	------	------
	48	1st year	------	------	------	------	28	21	43	15	------	------
		2d year	------	------	------	------	14	14	28	------	------	------

[1] November 1956 applications were 24 pounds per acre.

FIGURE 6.—Plots 2 years after treatment with 960 pounds per acre of sodium chlorate (left) and with 16 pounds per acre of 2,3,6-TBA (right).

Except on plots treated in November 1956, application of 16 pounds per acre 2,3,6-TBA resulted in satisfactory bindweed control. The apparent ineffectiveness of this treatment, especially 1 year after application, cannot be explained. Plant counts on plots treated with 32 pounds per acre were consistently low. As indicated in table 5, differences between 16 and 32 pounds were generally not large, and it is doubtful from a practical standpoint that use of the higher rate would be justified.

Many of the TBA and PBA applications did not control bindweed (table 5). The necessity of using higher rates was not recognized until 1957; therefore, comparatively few data are available from treatments at effective rates. However, it is apparent that 2,3,6-TBA was superior to TBA, and although some discrepancies existed, TBA was more effective than PBA when applied at the same rate.

Throughout the experimental period, differences in results following applications on the various dates were evident. Sufficient data have not been collected to assign any climatic factor or plant condition as the cause of these differences.

Six formulations of 2,3,6-TBA at 16 pounds per acre were compared in 1957. Table 6 gives the treatments and the number of plants growing on the plots in the fall of 1958 and 1959. The sodium salt, emulsifiable oil, and potassium salt formulations gave similar average results one year after treatment, but in the second year considerable regrowth occurred on plots treated in June 1957 with potassium salt. On the basis of these tests, the oil-soluble, lithium salt, and potassium salt formulations were somewhat less effective than the sodium salt and emulsifiable oil. A mixed metal salt of 2,3,6-TBA used on only one date was the least effective of the formulations tested at that time. Additional evidence is needed before conclusions can be drawn.

A comparatively small number of comparisons were made to determine the relative effectiveness of PBA applied as a spray and in dry, granular form (table 7). Under conditions of these tests, little dif-

TABLE 6.—*Average number of bindweed plants per square rod in the first and second year after treatment with 16 pounds per acre of several formulations of 2,3,6-TBA at Hays, Kans., 1957. All plant counts were made in the fall*

2,3,6-TBA formulation	Time after treatment	Surviving plants after treatment in—				
		June 1957	July 1957	October 1957	June and July average	June, July, and October average
		Number	*Number*	*Number*	*Number*	*Number*
Sodium salt	1st year	20	16	2	18.0	12.7
	2d year	23	24	2	23.5	16.3
Emulsifiable oil	1st year	33	1	------	17.0	----------
	2d year	35	2	------	18.5	----------
Oil soluble	1st year	22	62	------	42.0	----------
	2d year	34	25	------	29.5	----------
Lithium salt	1st year	96	9	38	52.5	47.7
	2d year	116	6	9	61.0	43.7
Potassium salt	1st year	40	8	7	24.0	18.3
	2d year	100	5	1	52.5	35.3
Mixed metal salt	1st year	------	------	45	--------	----------
	2d year	------	------	31	--------	----------

TABLE 7.—*Average number of bindweed plants per square rod in the 1st and 2d year after treatment with PBA applied as a spray and in the granular form at Hays, Kans., 1957. All plant counts were made in the fall*

Method of application	Rate	Time after treatment	Surviving plants after treatment in—		
			July 1957	October 1957	Average
	Lb. per acre		*Number*	*Number*	*Number*
Spray	16	1st year	18	44	31.0
		2d year	11	90	50.5
	32	1st year	27	14	20.5
		2d year	36	11	23.5
Granular	16	1st year	58	35	46.5
		2d year	95	20	57.5
	32	1st year	5	16	10.5
		2d year	11	16	13.5

ference in bindweed control by the two materials was noticed. Observations indicate that spray applications of PBA during periods of warm weather usually result in bindweed topkill within 1 week. The granular product had little immediate effect, but topkill was nearly complete in about 30 days.

Early in the experimental program it appeared that the chlorinated benzoic acids might prevent crop production on treated soil for only a relatively short time. Continued experimentation indicated, however, that benzoic acid residues were toxic to many plants and were rather persistent. Phillips (*18*) described distribution of the toxic residue on plots previously treated with 2,3,6-TBA and PBA at various rates.

When little effective rainfall was received, the treated plots remained nearly free of all vegetation. During periods of higher precipitation, weedy grasses such as tumblegrass (*Schedonnardus paniculatus*) and crabgrass (*Digitaria* spp.) and other shallow-rooted plants began growing on the plots a few months after treatment.

Annual weeds, such a fireweed (*Kochia scoparia*), exhibited symptoms similar to those caused by growth-regulators for as long as 3 years after treatment. Also, bindweed plants present in the fall of 1958 on plots treated with 16 pounds per acre of the sodium salt of 2,3,6-TBA in May 1955 showed extreme effect of growth-regulator type (fig. 7). These observations provide conclusive evidence that the chemical or phytotoxic products of its breakdown remain in the soil for extended periods.

Research is continuing to determine more fully the effect of phytotoxic residues on crop yields. However, results to date (1959) indicate

FIGURE 7.—Appearance in November 1958 of bindweed plants from a plot treated May 1955 with 16 pounds per acre of 2,3,6-TBA (left) as compared with a normal plant from a recently cultivated area (right).

that production of winter wheat and sorghum will be reduced for at least 2 years following treatment with chlorinated benzoic acids when these herbicides are applied at rates necessary for bindweed control. Soil type and amount and distribution of precipitation undoubtedly influence the rate of disappearance of the residues.

Other Soil Sterilants

In addition to sodium chlorate and the benzoic acid compounds, numerous chemicals were tested to determine their effect on bindweed. Table 8 compares several of these chemicals, as well as 2,3,6-TBA, with sodium chlorate. These data show that, while some of the compounds were quite effective, many of them were not satisfactory. Although only one rate of each chemical is listed in the table, each material was tested at two or more rates. When preparing the table either the lowest effective rate or the highest rate that was applied repeatedly was included.

Sodium chlorate results varied considerably. The relative ineffectiveness of the chemical during periods of drought was responsible for the large number of surviving plants listed for some of the comparisons. Because of the variation it was necessary to compare each of the chemicals with sodium chlorate applied on the same dates.

Many compounds tested were mixtures of two or more herbicides; therefore, the classification given in table 8 is somewhat arbitrary.

Boron Compounds

Applications of anhydrous borax and sodium chlorate were made in the spring, midsummer, and fall (table 8). Bindweed control ranged from excellent to poor, but results did not appear to be correlated with season of application. The boron compound is considered to be somewhat more persistant in the soil than is sodium chlorate, but it would be adapted for use in areas where long sterility is not a problem and where sodium chlorate might cause a fire hazard (fig. 8).

On the basis of the average of eight tests, CBM at 1,600 pounds per acre was somewhat inferior to sodium chlorate. Although it did consistently cause some stand reduction, even this comparatively high rate was not appreciably superior to sodium chlorate in any of the eight tests.

At the rates used, BDM was ineffective in all experiments. In many cases results during the first year after application were favorable, but regrowth during the second year after treatment indicated that bindweed roots had not been killed deeply enough to prevent recovery, nor was the chemical persistant enough to kill the emerging plants.

Urea Herbicides

Monuron and fenuron at 60 pounds per acre or more were consistently good bindweed control chemicals (table 8). No important differences in control with the two materials were noted (fig. 9). However, fenuron was less persistent in the soil. Monuron would therefore be preferred for use on areas where virtually complete soil

TABLE 8.—*Summary of direct comparisons of bindweed control with sodium chlorate and several other chemicals at Hays, Kans., 1952–58*

Compound comparisons	Rate	Comparisons	Years tested	Bindweed plants per square rod: 1st year after treatment	Bindweed plants per square rod: 2d year after treatment
	Lb. per acre	*Number*		*Number*	*Number*
2,3,6-TBA:					
Sodium chlorate	960	8[1]	1955–58	66	22
2,3,6-TBA	16			22	20
Sodium chlorate	960	5	1955–57	83	22
2,3,6-TBA	32			8	12
Boron compounds:					
Sodium chlorate	960	9	1952–57	92	58
Anhydrous borax	2, 560			65	53
Sodium chlorate	960	8	1952–57	101	65
CBM	1, 600			121	95
Sodium chlorate	960	5	1954–57	104	63
BDM	960			155	172
Urea herbicides:					
Sodium chlorate	960	8	1953–57	118	65
Monuron	60			67	29
Sodium chlorate	960	5	1953–55	108	65
Fenuron	60			55	17
Sodium chlorate	960	5	1955–57	81	40
CBMM	1, 280			162	133
Sodium chlorate	960	6	1955–57	93	37
BMM	1, 280			54	29
Sodium chlorate	960	2	1957	24	10
Monuron-TCA	60			84	166
Phenoxy compounds:					
Sodium chlorate	960	6	1954–57	111	55
2,4-D amine salt	60			211	202
Sodium chlorate	960	2	1955–56	76	18
2,4,5-T ester	60			198	231
Sodium chlorate	960	5	55–57	79	40
Silvex ester	60			147	176
Miscellaneous compounds:					
Sodium chlorate	960	6	1955–57	92	37
Erbon	160			148	209
Sodium chlorate	960	2	1955	110	74
Amitrole	12			262	324
Sodium chlorate	960	3	1957	17	7
Simazine	20			126	171

[1] Only 5 comparisons are included in the results for the 2d year after treatment.

FIGURE 8.—Appearance of an area two growing seasons after treatment with 2,560 pounds per acre of anhydrous borax.

FIGURE 9.—Plots 4 years after treatment with 80 pounds per acre of fenuron (left foreground) and with 80 pounds of monuron (right foreground).

sterility for long periods is desirable. Both chemicals were more persistent than sodium chlorate.

At 1,280 pounds per acre, BMM was essentially equal to monuron in all respects. CBMM treatments seldom resulted in satisfactory bindweed control. The lack of effectiveness of CBMM as compared to BMM appeared to be the result of the lower percentage of monuron contained in the CBMM product (1 versus 4 percent).

Data from only two experiments involving monuron-TCA are available, but these results indicated that the chemical was unsatisfactory for bindweed control at the rates tested.

Phenoxy Herbicides

As indicated by the number of surviving plants (table 8), none of the phenoxy compounds, as used, were effective herbicides for bindweed control. When applied at high rates these growth-regulating chemicals caused rapid foilage burn; therefore, it is doubtful that appreciable translocation occurred. The treatments often suppressed bindweed growth for 6 or more months, but there appeared to be too little residual action to maintain control. It was theorized that fall applications would result in slower breakdown of chemicals such as 2,4-D, and thus retain sufficient residue to accomplish control. However, treatments applied in the fall of 1955 and 1956 resulted in no better control than when applications were made in the spring or summer.

Of the three chemicals tested, silvex suppressed bindweed growth for the longest period; in a few instances for as long as 1 year (fig. 10). 2,4,5-T was more persistent than 2,4-D, but these differences were not important as none of the treatments resulted in satisfactory control. Observations of the action of 2,4-D and 2,4,5-T amide formulations indicated that these materials were no more effective than esters or amine salts.

Miscellaneous Compounds

Erbon was tested in 1955, 1956, and 1957. The chemical gave excellent suppression of bindweed for approximately 10 months, but was not effective in preventing vigorous regrowth.

Amitrole was entirely ineffective as a bindweed control herbicide.

Simazine was somewhat variable in its effect, but in most cases treatment with 10 or 20 pounds per acre caused only slight stand reductions. Vigor of the surviving plants was often increased, due to elimination of virtually all other vegetation by the chemical.

Controlling Bindweed With 2,4-D

Experiments with 2,4-D were begun in 1945, and new experiments were started each year until 1950. Three general formulations of 2,4-D were tested. These included ester, amine salt, and sodium salt formulations. Bindweed stands may be greatly reduced with 2,4-D, but even repeated applications will not, in most cases, com-

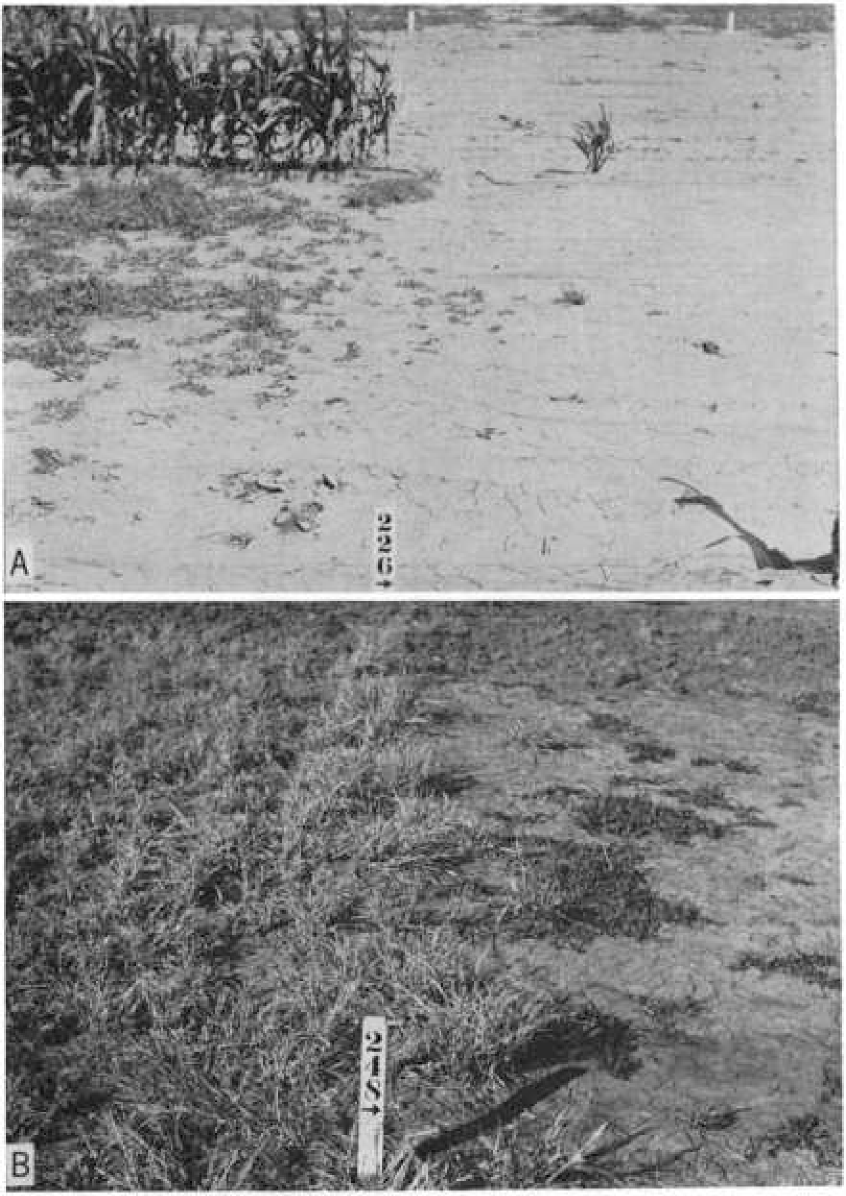

FIGURE 10.—Plots treated with silvex as contrasted with other treatments: *A*, 2 years after applications of 60 pounds per acre of silvex (left) and 960 pounds of CBMM (right); *B*, 1 year after applications of 32 pounds per acre of PBA (left) and 60 pounds of silvex (right). Silvex prevented grass growth but bindweed reinfested the plots.

FIGURE 11.—Stakes locate the bindweed plants that survived treatments with 1 pound per acre of isopropyl ester of 2,4-D for two successive years. Such areas quickly become reinfested.

pletely eradicate established stands. Applications of 2,4-D should be made when the weed is well emerged and growing vigorously, at the bud stage if possible. The rate of applications should be approximately 1 pound of 2,4-D acid equivalent per acre, applied in any formulation. Lighter rates have given somewhat erratic results (*20*).

In addition to these basic types, various commercial brands were evaluated, and in 1950 an experiment was begun to test effectiveness of various formulations of 2,4-D ester, 2,4,5-T, and 2,4-D acid (fig. 11). These formulations were compared with an amine of 2,4-D and with the amine plus a wetting agent (table 9). Since 1950 a few small experiments have been conducted.

In all the 2,4-D experiments, the plots were re-treated in years following the original application. In no case were all of the replicates of any one treatment completely free from bindweed even after four applications of 2,4-D. It usually was possible to eliminate more than 95 percent of the original stand of bindweed, but nearly always sufficient bindweed remained to reinfest the area if control methods were not carefully followed every year. Reinfestation was observed when the experimental plots started in 1946 were allowed to remain untreated in 1951 and 1952. By the end of 1951 the infestation was approximately 50 percent of the original stand and by the end of 1952 the area was almost completely reinfested. This reinfestation was the result of both seedling establishment and the spread of established plants not eradicated by the chemicals applied while the experiment was in progress.

TABLE 9.—*Comparison of several formulations of 2,4-D and 2,4,5-T for field bindweed control at Hays, Kans. Original treatment was applied June 14, 1950*

Chemical	Formulation	Rate	Plants per square rod		
			Prior to treatment	1 year after treatment	1 year after re-treatment [1]
		Lb. per acre	*Number*	*Number*	*Number*
2,4-D	Triethanol amine salt	½	315	122	78
		1	204	57	18
		2	312	105	91
2,4-D	Propylene glycol butyl ether ester.	½	363	186	115
		1	402	81	23
		2	325	40	15
2,4-D	Butoxy ethanol ester	½	317	146	62
		1	367	164	53
		2	353	119	35
2,4-D	Emulsifiable acid	½	446	205	81
		1	321	82	16
		2	396	114	23
2,4,5-T	Butoxy ethanol ester	½	352	71	41
		1	284	41	23
		2	227	52	52
2,4-D	Triethanol amine salt +0.5 percent wetting agent.	½	356	153	26
		1	510	111	47
		2	402	94	11

[1] Re-treatments were applied at the same rates approximately 1 year after original treatment.

Controlling Bindweed With 2,4-D, Combined With Competitive Crops and Intensive Cultivation

Shortly after beginning experiments with 2,4-D on bindweed, it became apparent that the chemical in itself would only control the weed, seldom eradicate an established stand. A series of experiments was conducted from 1947 to 1949 to use the best knowledge accumulated concerning intensive cultivation and competitive crops with the better times and rates of applying 2,4-D to bindweed.

The two most effective methods reduced bindweed stand to approximately 1 plant per square rod in 3 years with an average of 11.3 to 13.3 cultivations and 2.7 pounds of 2,4-D an acre (*20*).

These methods appeared slightly more effective than spraying with 2,4-D without intensive cultivation, which required 4.0 pounds of 2,4-D an acre and 6.7 cultivations in 3 years, or intensive cultivations without 2,4-D, which required 18.0 cultivations in 3 years to reduce bindweed stand to 10 plants to the square rod.

Numerous other experiments were carried out from 1946 through 1951 with crops competing with bindweed and with periods of intensive cultivation. Results showed that 2,4-D could be used to substitute for some of the intensive cultivation and to reduce the bindweed stand early in the treatment period. However, it is doubtful that the time necessary for eradication was reduced signficantly over good competitive crop and intensive cultivation methods. Fall-planted wheat, spring-planted oats or barley, and early-summer-planted close-drilled sorghum all proved effective in helping 2,4-D reduce the stand of bindweed. Sorghum planted in 40-inch rows was not effective as a competitor and resulted in reductions of stand similar to those when 2,4-D was used alone.

Controlling Bindweed Seedlings

Continued emergence of bindweed seedlings many years after the original stand has been eliminated complicates bindweed control. Results of experiments and observations reported by Timmons (*26*) indicated that completely ridding infested fields of bindweed may require 30 years or more of persistent attention to a special program of farm management until all the seeds have germinated and been destroyed.

Experiments were started in 1938 to compare the effectiveness of several different crop rotations and cropping methods in controlling bindweed seedlings. It was shown that several commonly grown crops and certain cropping systems would satisfactorily prevent reinfestation of farmland from which the original stand of bindweed had been eradicated. The choice of crops appeared to be limited to vigorously growing, close-drilled annual crops. Row crops, such as grain sorghum, grown in consecutive years, did not prevent reinfestation. Perennial grasses developed competition too slowly and skips in thin stands provided continuous opportunities for bindweed seedlings to become established.

Periods of intensive cultivation and occasional seasons of summer fallow between annual crops seemed to be highly important in bindweed seedling control. Cultivation during such periods should be repeated once a month during the growing season. The common practice of leaving small-grain stubble land idle and uncultivated until spring almost always permitted bindweed seedlings to become established. A uniformly good stand of a close-drilled crop was essential to control the seedlings.

Crops and cropping systems that proved quite satisfactory for bindweed-seedling control included winter wheat and close-drilled sorghum grown every year or a rotation of wheat, row sorghum, and summer fallow supplemented with monthly cultivation when the land was not in crop.

It is possible to use 2,4-D to considerable advantage in a bindweed-seedling control program, as the seedlings are quite susceptible to 2,4-D. This chemical may be substituted for some of the cultivation operations in the seedling-control program and may, in some instances, be used to control the seedlings that emerge in a thin stand of a competitive crop. Also, 2,4-D may be used to advantage in controlling bindweed seedlings in perennial grasses.

SUMMARY

Results from experiments on controlling field bindweed (*Convolvulus arvensis* L.) at the Fort Hays Branch Station of the Kansas Agricultural Experiment Station, 1935–58, are presented. This period has included both extremely wet and extremely dry seasons. The average yearly precipitation for the period differs little from the 91-year average, 1868–1958.

Grain and forage yields of nine different crops grown with methods comparable to average farm practices were reduced from 20 percent to nearly 80 percent by bindweed. Wheat and other small grains produced more nearly normal yields on infested land than did sorghums and other summer-growing crops.

Intensive fallow usually eliminated the bindweed in two seasons or less, provided cultivations were at the proper time and with proper implements. Cultivation operations performed 12 days after each bindweed emergence resulted in bindweed eradication with an average of 16.2 cultivations. This compared with an average of more than 32 cultivations when the operation was performed each time the bindweed emerged. No advantage was found for cultivating bindweed deeper than necessary to cut off all plants well below the surface. The optimum depth in the medium heavy soil at Hays, Kans., was 4 to 6 inches.

The cultivation could be started either in the spring of the year soon after bindweed growth starts or after small-grain harvest, provided there is sufficient moisture to promote bindweed growth and permit thorough tillage. No advantage was found for cultivating bindweed when there was not sufficient moisture to promote its growth. The cultivation operations had to be continued until September 15 or October 1 to prevent partial recovery of the bindweed.

One year of intensive fallow and three crops of wheat seeded early in October after intensive cultivation between harvest and seeding each year eradicated bindweed in 3 to 4 years and proved to be a practical plan for the Hays area. Alternate fallow and wheat and a rotation of 1 year of fallow and 2 years of wheat also appeared to be good methods.

Either close-drilled sorgo or sudangrass seeded about July 1, after a period of intensive cultivation, proved to be an effective competitor with field bindweed. The success of all competitive crops depended upon intensive cultivation during the bindweed growing season when the land was not in crop and upon obtaining a good stand of the crop.

Sodium chlorate was tested extensively throughout the experimental period. Little difference was noted in results of spray or dry applications of sodium chlorate. Results with rate and date of application were somewhat variable from year to year, but it appeared that September and October were the most favorable months for application. An original application of 3 to 4 pounds per square rod, followed by re-treatments in subsequent years, generally was the most economical method at Hays.

Three chloro-substituted benzoic acid compounds were applied at several rates on several dates from 1955 to 1958. All materials contained mixtures of variously substituted acids and isomers, but they

were designated as 2,3,6-trichlorobenzoic acid (2,3,6-TBA), trichlorobenzoic acid (TBA), or polychlorobenzoic acid (PBA). At 16 or more pounds per acre, 2,3,6-TBA was equal or superior to 960 pounds per acre of sodium chlorate for controlling field bindweed and 2,3,6-TBA was less dependent on rainfall. At a given rate of application, 2,3,6-TBA was most effective, TBA next, and PBA least effective of the benzoic acids. It appeared that PBA should be applied at about twice the rate of 2,3,6-TBA. Some shallow-rooted vegetation grew on treated areas a few months after applying these chemicals, but residues sufficient to reduce wheat and sorghum growth persisted for 2 or more years.

Of the several other soil-sterilizing chemicals tested, only anhydrous borax, monuron, fenuron, and BMM were consistently effective in reducing stands of bindweed. These four chemicals were equal or superior to sodium chlorate, but caused the soil to remain unproductive for a longer time than did sodium chlorate.

Bindweed stands were greatly reduced with 2,4-D, but even repeated applications did not, in most cases, completely eradicate established stands. Applications of 2,4-D were most effective when the weed was well emerged and growing vigorously, at the bud stage if possible. One pound of 2,4-D acid equivalent per acre, applied in any formulation, was as effective as higher rates. Lighter rates gave somewhat erratic results. Best results with 2,4-D were from applying the chemical following a short period of intensive cultivation.

Bindweed treatment with 2,4-D was combined with some of the better methods of intensive cultivation and competitive crops. Using the chemical in these systems added considerable convenience to the methods, but use of 2,4-D probably did not greatly hasten eradication of the weed. Using 2,4-D had the advantage of giving greater reductions early in the eradication program than intensive cultivation and competitive crop methods.

Bindweed seedlings continue to emerge in large numbers for many years after the original stand has been eradicated. Persistent attention to a special program of farm management is necessary to prevent these seedlings from becoming established as perennial plants. Proper use of 2,4-D may aid considerably in preventing this reinfestation. Periods of intensive cultivation and an occasional season of summer fallow between crops along with the use of close-drilled crops are important in bindweed-seedling control.

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LIST OF CHEMICALS

The following is a list of chemicals discussed in this bulletin, together with accepted common names or abbreviations. Common names are used throughout the text.

Chemical Name:	*Common Name*
Sodium chloride	salt
Sodium chlorate	sodium chlorate
Anhydrous borax (61.5 percent B_2O_3 equiv.)	anhydrous borax
25 percent sodium chlorate–71 percent borate mixture	CBM
90.5 percent borate–7.5 percent 2,4-D mixture	BDM
40 percent sodium chlorate–57 percent borate–1 percent monuron mixture.	CBMM
94 percent borate—4 percent monuron mixture	BMM
3-(p-chlorophenyl)-1,1-dimethylurea	monuron
3-(phenyl)-1,1-dimethylurea	fenuron
3-(p-chlorophenyl)-1,1-dimethylurea trichloroacetate	monuron-TCA
2,4-dichlorophenoxy acetic acid	2,4-D
2,4,5-trichlorophenoxy acetic acid	2,4,5-T
2-(2,4,5-trichlorophenoxy)propionic acid	silvex
2-(2,4,5-trichlorophenoxy)ethyl-2,2-dichloropropionate	erbon
3-amino-1,2,4-triazole	amitrole
2-chloro-4,6-bis(ethylamino)-s-triazine	simazine
2,3,6-trichlorobenzoic acid	2,3,6-TBA
trichlorobenzoic acid	TBA
polychorobenzoic acid	PBA

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